Stochastic Methods for Flow in Porous Media, Coping with Uncertainties

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Flow of water in sub-surface geologic environments takes place through an array of interconnected pore spaces, the spatial distribution of which eludes us. The presence of complex variations in water pathways and geologic characteristics produces large spatio-temporal fluctuations in the values of the variables describing water flow and/or transport of contaminants. The situation is accentuated by the small number of measurements that are usually available in groundwater studies, the dependence of parameter values onto instruments' resolution, measurement and interpretation errors during sampling procedures, and model uncertainties in the description of a hydrologic system.

Traditionally, analyses of groundwater problems relied on solution of partial differential equations that required precise definition of parameters, water sources or sinks, and conditions at the boundaries of the hydrogeologic system. However, and in addition to the hydrogeologic parameters' variation, one typically has to estimate water inputs or outputs to aquifers from agricultural activities, leakage from lagoons, lakes, or other sources of surficial water in an area, and to a large extent hypothesize the hydraulic conditions at the boundaries of aquifers. This combination of spatio-temporal variation, measurement error, and uncertainty has led in the last 30 years to the development of stochastic sub-surface hydrology.

The stochastic framework views parameters and variables no longer as deterministic, but rather, it treats them as exhibiting random fluctuations from one point to another. At the same time, due to the underlying geologic continuity, it views them as remaining correlated over distances and with each other; or, as defined in geostatistical terminology, as random fields. *Stochastic Methods for Flow in Porous Media, Coping with Uncertainties*, written by one of the most active researchers in the area of stochastic hydrology, surveys a broad range of approaches used by scientists in the sub-surface hydrologic community, and presents some of the most recent accomplishments in the development of stochastic methods.

The book commences with a discussion of one-dimensional saturated and unsaturated flows, and uses these two simple cases to illuminate the influence of various sources of uncertainty. This task is accomplished by separately analyzing cases of uncertain water inputs or sinks, such as those encountered during agricultural applications; cases of varying boundary conditions, such as of aquifers connected to rivers of fluctuating stages; or by investigating cases of heterogeneous hydraulic conductivity fields. The book thus highlights early on the need for stochastic concepts and techniques to real flow problems and naturally introduces the reader to these topics.

Although the book requires some mathematical sophistication, the topics are presented in a tutorial way so that knowledge of the theory of stochastic processes is not an a priori requirement. The brief overview of random field theory should suffice for helping readers follow the development of methods presented in subsequent chapters.

The introductory material is expanded in chapters 3 and 4 to cover the more general cases of three-dimensional, steady-state, and transient saturated flows, respectively. Chapters 5 and 6 present three-dimensional unsaturated (both steady-state and transient) and two-phase flows, respectively; while chapter 7 is dedicated to flow in fractured porous media. Uncertainty is introduced in all cases by the presence of heterogeneous material through which flow takes place, as well as from uncertain sources/sinks and boundary conditions.

The chapters introduce a number of stochastic methods that allow computation of the statistical moments for variables, such as hydraulic head and flux, which are of interest to hydrogeologic studies. Techniques such as perturbation expansions, spectral methods, adjoint methods, Green's function methods, and closure approximations—which have been used in the hydrologic literature to develop solutions—are covered extensively. Numerical applications and a large number of examples are an added bonus that this book offers, as these help illustrate the practical use of mathematical techniques.

Given the complexity of the topic, the book succeeds admirably in presenting the material in as straightforward and reader-friendly a manner as possible, by illustrating the advantages and limitations of each technique to the problem at hand, or by showing that results can be developed independently through different approaches. In that respect, both an advanced audience that has been exposed to the stochastic groundwater literature, and a novice reader of this material have a lot to gain by exposure to the arsenal of tools utilized today in the field of stochastic hydrology. Perhaps the most important aspect offered by the book is the complete and authoritative manner with which the topics are covered, thus allowing stochastic sub-surface hydrology to claim that it has outgrown the research environment, and is ready for use by practicing hydrologists.

—EVANGELOS K. PALEOLOGOS, University of South Carolina, Columbia

ABOUT AGU

Schubert Receives 2002 Harry H. Hess Medal

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Gerald Schubert was awarded the Hess Medal at the AGU Fall Meeting Honors Ceremony, which was held on 8 December 2002, in San Francisco, California. The medal is given for outstanding achievements in research in the constitution and evolution of Earth and sister planets.

Citation

"It is good we are here this evening, not only to honor our friend and colleague Jerry Schubert, but also, perhaps as important, to set the record straight. Otherwise, it is likely that centuries from now historians will struggle with the mystery of whether Gerald Schubert was one person or, rather more plausibly, a pseudonym for a group of individuals. Great effort could be expended on this enigma, tracts written, conferences held, university departments created, and countless academics gainfully employed. But we here tonight can save them all the trouble and expense.

"For although Jerry Schubert is an incomparable polymath, with a list of major contributions to make us seethe with jealousy, we can attest to the fact that he is indeed just one man. However, Jerry's prodigiousness and diversity aside, what is most remarkable is that so many of his contributions have endured to become classics of geophysics. Many of us would be happy to make a lasting impression in one field; but to have made such an impression in so many fields is simply extraordinary, not to mention intimidating. Since Jerry has more papers than words

'officially' allowed in this citation, I will give you only a brief flavor of some of his major contributions.

"Jerry began his career in aeronautical engineering in the 1960s, but was coaxed first into astrophysics, and then later into planetary